

The Economist

Can Winston Starmer pull it off?

Germany rearms

Time to lift Syria's sanctions

RIP foreign aid

MARCH 8TH-14TH 2025



**The
revised
economic
outlook**

Business



Photograph: AP

Donald Trump carried out his threat to impose tariffs of 25% on most goods imported to the United States from Canada and Mexico (he gave the car industry a one-month reprieve). He also increased the tariffs America imposes on Chinese exports from 10% to 20%, which are in addition to US trade duties that China is already subjected to. The American president warned that he would soon also introduce “reciprocal tariffs” on any country with “unfair” trade imbalances. Canada’s prime minister, Justin Trudeau, said the tariffs were “a dumb thing” and imposed retaliatory levies on a range of American products, including peanut butter. China also applied counter-measures and Mexico said it would react soon.

GDP deflator

Mr Trump says his tariffs policy will bring only “a little disturbance” to the American economy. Markets think otherwise. The S&P 500 and NASDAQ Composite fell sharply and are back to where they were when Mr Trump was elected, wiping out their gains since November. The Stoxx Europe 600 and German DAX also fell heavily. Various companies, including Target, warned that the tariffs would

lead to higher costs and hurt profits. Meanwhile, some economists weighed the risk of recession from the trade war.

The European Central Bank cut interest rates again, reducing its deposit facility by a quarter of a percentage point, to 2.5%. The bank said the “disinflation process is well on track.” But with the euro area’s economy already flatlining before America’s new tariffs came into effect, markets think it was the last rate cut for a while.

Mr Trump suggested that TSMC, based in Taiwan and a global powerhouse in chipmaking, would avoid tariffs, after it decided to invest an extra \$100bn in America and open three new factories in addition to the one that is set to start full production this year. TSMC describes it as the single largest foreign direct-investment ever in America. Mr Trump used the announcement to call for ditching Joe Biden’s CHIPS Act, arguing that the subsidies it provides are a “horrible, horrible thing”.

Anthropic, the startup behind the Claude generative artificial-intelligence models, raised \$3.5bn in its latest round of fund-raising, tripling its valuation to \$61.5bn. Anthropic is backed by Amazon and Google as well as venture capitalists. It recently released Claude 3.7 Sonnet, which it describes as the “first hybrid reasoning model on the market”, allowing users to choose when it should answer normally and when it should “think” longer before answering.

A federal judge rejected Elon Musk’s request for a preliminary injunction to stop OpenAI’s attempt to change its status from non-profit to for-profit, but said she would fast-track his case this year. Mr Musk was one of the startup’s founders but has been feuding with it for years over what he claims is a shift away from its original intention to work for the good of humanity.

Apple reportedly started a legal challenge in Britain to the government’s order to create a back-door for British intelligence to its encrypted cloud services. The company recently withdrew its Advanced Data Protection tool for the iCloud from the British market rather than accede to that order. Donald Trump has likened the British request to access private data of Apple users to the practices of the Chinese state.

Microsoft is shutting down Skype, the video-calling service that it bought in 2011. Skype came to market in 2003 and was a pioneer in enabling video chats across the globe, but it has since been eclipsed by smartphones, Google Meet, Zoom and the like.

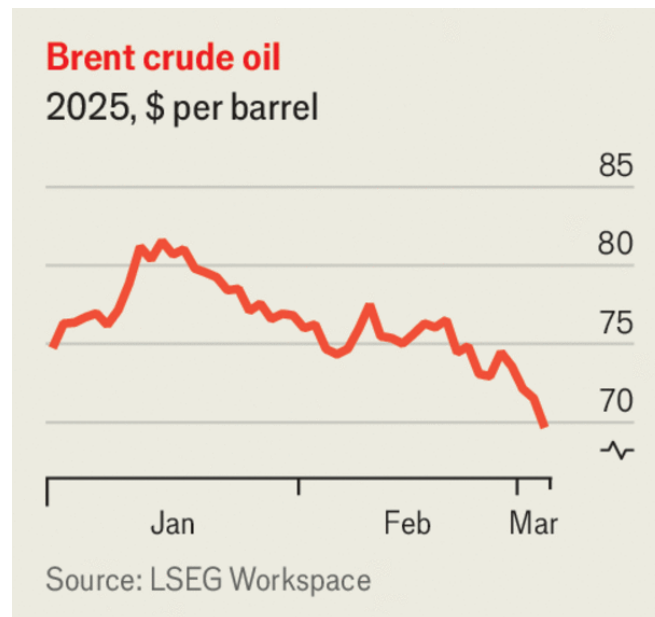


Chart: The Economist

Oil prices tumbled to three-year lows, as markets speculated that Mr Trump’s trade war would hurt the global economy. Another factor was the unexpected decision by OPEC+ to proceed with a plan to raise output in April. The cartel had hitherto placed curbs on production to boost prices. Its announcement may be designed to pre-empt another clash with Donald Trump, who wants to see a big drop in the commodity’s price.

The new chairman of the Federal Communications Commission, Brendan Carr, sent a letter to Verizon warning it about its promotion of diversity, inclusion and equity practices, linking it to a veiled threat about Verizon’s “pending transactions” at the FCC. The telecoms giant is seeking regulatory approval for its takeover of Frontier Communications. Mr Carr’s letter drew a sharp rebuke from a fellow commissioner at the FCC. Geoffrey Starks said it set a “dangerous precedent” that could “chill investment”.

A frothy market

Mixue’s share price soared by 43% on its first day of trading on the Hong Kong stock exchange. The Chinese company sells flavoured teas and soft-serve ice-cream and is the best known purveyor of bubble tea, a milky brew containing chewy tapioca balls. Its growth over the past few years has been phenomenal. Mixue now has over 45,000 franchised stores across Asia and Australia, more than McDonald’s or Starbucks have worldwide.

Aid cannot make poor countries rich

For decades, officials have promised to raise economic growth. For decades, they have failed



Illustration: Rose Wong

The capital of Malawi, one of the world's poorest countries, runs on aid. A city built in the 1970s by the World Bank, Lilongwe's straight streets are filled with charities, development agencies and government offices. Informal villages house cooks and cleaners for foreign officials; the entrance to each is marked with the flag of its national sponsor. Over the past five decades, policymakers have reached a division of labour: Britain funds schools, Japan backs energy projects, Europe supports agriculture and Ireland nurtures a cottage industry of justice activists. In the health ministry, maintained with Chinese money, doors are labelled by donor, not department. Many read "USAID".

When, just over a month ago, Donald Trump froze funding for the agency through which America doles out most of its aid, crucial work stopped overnight. Although a later waiver allowed "life-saving"

projects to restart, it applied only to those with approval from local development diplomats, most of whom had been put on furlough. Few projects have restarted. In Malawi maternal-health and refugee-support charities have ceased work and do not expect to open their doors until after Mr Trump's 90-day order elapses. At the same time, however, many projects that stopped were of a different nature. They were not saving lives. Instead, they focused on a more material aim: to make Malawi richer.

Mr Trump's decision is an extreme example of a broader trend. On February 25th Sir Keir Starmer chopped Britain's aid budget from 0.5% to 0.3% of gross national income to spend more on defence. France, the most generous Western donor after America, will this year reduce aid by 35%. Germany is considering cuts, too. Polling indicates broad domestic support for these decisions. Most big-name economists, including at the IMF and the World Bank, still insist on the importance of development spending—that intended to make countries richer—but even this consensus is fraying: some influential development economists now question how much good such spending really does. Could something better emerge from the mess?

Paper trail

First consider where money currently goes. Rich countries spent \$256bn (or 0.4% of GDP) on foreign aid last year—enough to provide sub-Saharan African governments with a sum as large as their total tax revenues. Only a sliver of the spending will have gone to cultural causes, funding the sort of pro-democracy charities and independent newspapers that MAGA types despise. Around a quarter will have been humanitarian aid (covering disaster relief and refugees) and health funding (such as HIV treatment, vaccines and so on). Cuts to American and British spending have mainly provoked concern about what will happen to recipients of this sort of aid.

But by halting USAID Mr Trump has also paralysed a much larger system dedicated to boosting economic growth. Development spending accounts for almost three-quarters of all aid. It most often subsidises favoured industries, frequently funds infrastructure construction and sometimes pays the salaries of teachers. The average Malawian has had more money spent on them by international agencies than by their own government every year since the country gained independence from Britain in 1964. Lilongwe's current state shows development aid's ambitions; the country's poverty reflects its failures.

Development agencies were first established to support newly independent colonies. Inspired by the Marshall Plan, which rebuilt post-war Europe with American money, President John F. Kennedy set up USAID in 1961. The promise was that a richer world would be both better for the worst-off and friendlier to the countries financing its growth. Aid economists treated poor countries as small rich

ones that simply needed extra public investment. Some agencies of that era, supposedly temporary, are still doling out cash.

In the years after the cold war, bilateral aid often linked handouts to democratic reforms, since policymakers believed that autocratic rulers held their countries in poverty. Then, in the early 2000s, development took on a more universalist hue; the focus shifted to building human capital through improved schooling and health care. From 2004 to 2014, aid spending increased by 75%. “There was a real feeling,” says Stefan Dercon of the University of Oxford, “that if there was a time things were going to get going, this was it.”

Things did not get going. From 2014 to 2024, the world’s 78 poorest economies grew more slowly than in the decade to 1970, when aid was first emerging. This is perhaps unsurprising, given earlier studies. In 2004 William Easterly of New York University and co-authors found that, from 1970 to 1997, aid was just as likely to shrink the world’s poorest economies as to help them grow. A year later the World Bank produced a post mortem on two decades of development aid, poring over the history of its recipients. The researchers concluded that its grants and loans did not move the needle on growth. In 2019 the IMF reached a similar conclusion. As Charles Kenny of the Centre for Global Development, a think-tank, notes: “There is no country that has really grown from aid.”

Each generation of development spending has failed in its own way. Early efforts built a lot of bridges, many to nowhere. In 2005 David Dollar and Jakob Svensson, both then of the World Bank, and Dani Rodrik of Harvard University, looked at disbursements tied to political reforms—and could not find a country where they had produced better policy. National leaders were concerned with staying in power; a desire strong enough to warp whatever advice, and however much money, aid bureaucrats provided. Earlier work by Dollar had found that aid simply magnified governments’ existing tendencies, speeding growth in countries that were willing to push through macroeconomic reforms and slowing it in those which were not, of which there were just as many. The problem was simple: there was no way to tell which bucket a country would fall into before handing over the money.

Health spending has had some real successes. The provision of HIV treatment helped halve deaths from AIDS in the two decades to 2020, for instance. But it has not prompted economic growth. Similarly, research has found little link between primary-education aid and output. In 2015 Axel Dreher of Heidelberg University and Steffen Lohmann, then at the University of Göttingen, looked at local economic activity after the building of schools, social housing and other projects in a range of locations, and found no increase in the amount of electric light, their proxy for economic growth. There were not enough businesses to make use of locals’ new skills, he theorised. And instead of strengthening recipient countries’ ability to provide public services, aid often weakens it. The IMF has

found that more development spending tends to result in lower taxes. Last year Avi Ahuja of New York University concluded that it produces less competitive political systems, as incumbents wield the cash to win votes.

More recently, disillusioned economists have turned to the work of Esther Duflo, a Nobel laureate at the Massachusetts Institute of Technology, who uses randomised controlled trials to study interventions. Yet she has come to a dispiriting conclusion: there is no reason why what works in one neighbourhood will do so in the rest of a district, let alone on another continent. In one Indian village, for instance, giving women pensions made their granddaughters (if not their grandsons) healthier; in another, handouts failed to improve health or even raise household consumption. Ms Duflo's findings chime with other research. In Bangladesh free health care killed private provision. In Africa aid-funded hospitals struggled to absorb knowledge from American doctors.

Orphaned

What lies behind this failure? Aid organisations are often criticised for wasting money on bureaucracy. In reality, they face a more fundamental problem: they have no idea how to encourage economic growth. The theory behind most Western aid has been staunchly liberal (in the British sense) for decades. Officials hope to build a private sector that can export to global markets, schools capable of furnishing firms with workers and infrastructure that will attract investment. Recipients are encouraged to dismantle regulation that stands in the way of free markets and to curtail unnecessary spending.

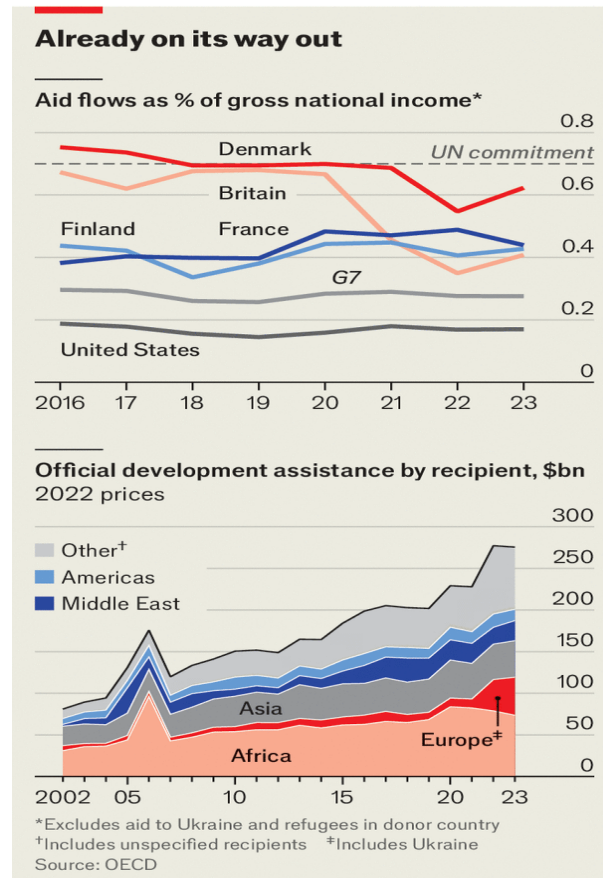


Chart: The Economist

Yet it is hard to hand out enormous sums without turning poor countries into miniature command economies. Development projects mostly attempt to build entire industries, such as dairy farming or fisheries, from scratch. Disbursal conditions can have a faintly Soviet air. In 2022 a typical grant to Tanzania’s fishing industry, funded in part by America, demanded a fivefold increase in production over the next 15 years.

Many problems are similar to those that plague industrial policy in rich countries, not least when picking winners. In 2015 Lindsay Whitfield of Copenhagen Business School and co-authors looked at 14 African industries that received aid. They found that after handouts just two had raised output. Western aid officials often want to prevent local politicians, who control crucial industries, from profiting as a result of their projects, meaning they select obscure sectors for tax breaks, credit and subsidies. With few investors willing to stump up capital, and little interest from local politicians, the businesses duly flop.

Recipient countries have created entire bureaucracies devoted to planning, securing and documenting aid. The Malawian state, for instance, employs many more people to manage aid than to oversee trade. There is a reason for this. After 60 years of disbursements, the world's poorest countries provide public services beyond what would otherwise be possible with their tax revenues. Many also rely on assistance to keep foreign reserves cushioned, lifting living standards. "The first reason we can't survive without aid is that it is all our dollars," says an African official.

This makes any cuts to development spending, no matter how inefficient, a nightmare. National leaders protest that they will have to reduce spending on clinics or schools, or resist loosening a currency peg. Indeed, adroit politicians must both work with donors, so as to keep services running, and dodge the difficult reforms they seek, so as not to upset voters. The governments of Egypt, Kenya and Pakistan all find themselves caught in this pattern, with politicians punished when they fail to keep both sides happy. Protests have broken out in Cairo, Nairobi and Karachi in the past year when politicians have accepted reforms sought by development outfits. Ultimately, their survival depends both on receiving aid and not enacting the sort of policies that might, in time, reduce their dependence on such handouts.

Moreover, it is not just governments that are warped by aid. In many countries, everything from the banking system to import permits is designed to accommodate donors' needs. Embryonic industries that are not favoured by aid officials barely stand a chance. Every year the best-connected and most-educated Malawians return from university abroad not to start a business, but to start a charity. On a weekday they pack out Lilongwe's smarter dining spots, meeting with diplomats. Most live a stone's throw away from downtown, on the site of offices paid for by aid agencies, and enjoy salaries far beyond those available in the private sector.

At the annual meetings of the UN, the World Bank and the IMF, which serve as informal AGMs for international policymakers, developing-world politicians admonish aid officials for granting them insufficient respect. The less aid works, the more stringent donors become—in the hope of turning things round—and so the larger recipient countries' aid bureaucracies grow. Poor countries do not welcome the cash, which has become a fact of life; they resent the conditions with which it arrives. William Ruto, Kenya's president, wants no-strings-attached money as compensation for decades of botched development.

Instead, the next generation of aid is likely to be even more strategic, and less concerned with saving lives. "I continue to support foreign aid," Marco Rubio, America's secretary of state, has said, "but foreign aid is not charity. It exists for the purpose of advancing the national interests of the United States." This builds on earlier policy (under Barack Obama, USAID negotiated labour-migration agreements between Europe and Latin America to reduce pressure at America's border) and mirrors

moves in other parts of the rich world. In 2020 Britain merged its development agency with its foreign office.

Aid is about to be weaponised. The hard-nosed enforcers of the emerging approach are willing to sacrifice spending that did lots of good, including vaccination regimes, infectious-disease control and other interventions. In one of Lilongwe's public gardens, a bureaucrat formerly in charge of USAID's east Africa office lists the many clinics, schools and government offices now under threat. The idea that Malawi's clinics might never re-open is agonising for aid workers, and uncomfortable for anyone who believes rich countries have an obligation to help the world's poor. Nevertheless, that public life in many of the world's poorest countries has ground to a halt on the whim of Mr Trump reflects how badly—rather than how well—much of the old system worked.

Why silver is the new gold

Safe-haven demand and solar panels have sent its price soaring

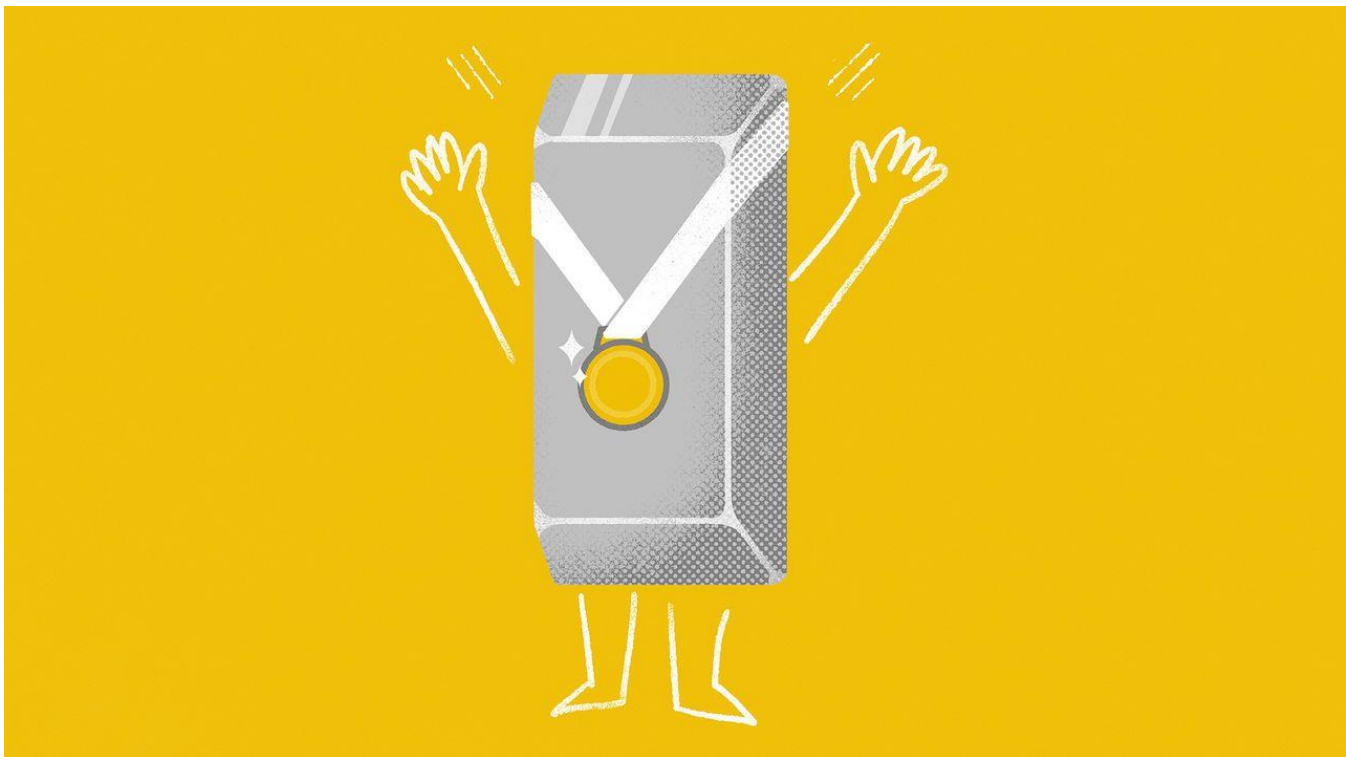


Illustration: Satoshi Kambayashi

It is a fabulous time to be a gold bug. Not long ago, outing yourself as one was a good way of getting people to back away from you at an investment conference. The popular image was of someone in possession of their own electricity generator, stacks of water-purification tablets and several years' supply of tinned food. Now it just features a shrewd investor. Since the start of 2023 the shiniest asset's price has soared by nearly 60% in dollars. That is more than any of the world's leading share indices—including, after a turbulent couple of weeks, America's S&P 500.

Yet the sweetest vindication goes to fans of another precious metal. Even gold enthusiasts tend to view an ardent interest in silver as somewhat eccentric. To traders it is the “poor man's gold” or “the devil's metal”. For years those nicknames were justified by silver's lacklustre returns and the wild ride its price took along the way. The devil's metal is still not for the faint-hearted. But it has almost kept pace with gold over the past year and has outperformed it over the past five. With investment flows now following returns, a once-niche asset is inching towards the mainstream.

Logic suggests that silver's price should move similarly to gold's. It, too, is rare, pretty and inert, and so has been used to forge jewellery and coins for millennia. This long-established role as a store of value lends it “safe-haven” appeal when investors are nervous. As with gold, the fixed amount of silver in the Earth's crust ought also to make it a good hedge against inflation. Sure enough, both metals' recent rallies came as investors fretted over geopolitical chaos and persistently rising prices. In doing so they overcame another common tendency, for their prices to fall when real interest rates rise and vice versa, since they generate no income.

So much for theory. In practice, different levels of mining supply and industrial demand ensure that the silver-to-gold price ratio is changing all the time. Over the long term, that has led to decades of disappointment for silverites. For most of the 1970s you would have needed to sell 30 to 40 ounces of silver to buy one of gold. Today it would be more like 90.

Speculators have been burned by the devil's metal, too. After the global financial crisis of 2007-09, faltering industrial demand and a spotlight on haven assets meant silver's price depended more than ever on traders' whims. As a result, the silver-to-gold price ratio spent years moving in line with the gold price. A bet on silver became an amplified bet on gold—a relationship cherished by hedge funds, which would usually have had to pay for a margin loan to obtain such leverage. The relationship then fell apart towards the end of the 2010s, causing traders relying on it to lose their shirts, as silver abruptly fell out of fashion with investors.

Now it is back in vogue. Central banks have spent years building up their gold reserves. In September Interfax, a Russian news agency, reported that its government would soon start buying silver, too. Last

year was the first since 2021 that silver exchange-traded funds, which individuals use to buy commodities, saw net inflows. This year traders in New York have been draining London's vaults of gold, amid fears that such imports may face tariffs in the future. They have been snapping up silver even faster—so much so, in fact, that the transatlantic price gap justifies loading bars of it onto commercial flights.

What is more, a widening gulf between supply and demand looks likely to keep the frenzy going. The annual supply of silver, driven by mining production and recycling, has contracted slightly over the past decade, according to the Silver Institute, a research outfit. Over the same period, industrial demand has surged by more than 50%, owing largely to silver's use in solar panels. Imports into China, which manufactures large quantities of these, have shot up. Since mining capacity cannot be expanded quickly, the imbalance should continue to boost silver's price for some time.

As the world becomes a more fractious place, it is hard to imagine investors' demand for haven assets falling soon. Meanwhile, the incentives for governments to store value in places beyond the reach of Uncle Sam are growing. That is a big reason why central bankers have been buying so much gold of late. Some may be tempted, along with Donald Trump, to include cryptocurrencies in their reserves. But there is another precious metal that could do the job, too. It is time for silverites to come in from the cold.

It is not the economic impact of tariffs that is most worrying

What are the lessons of the 1930s?

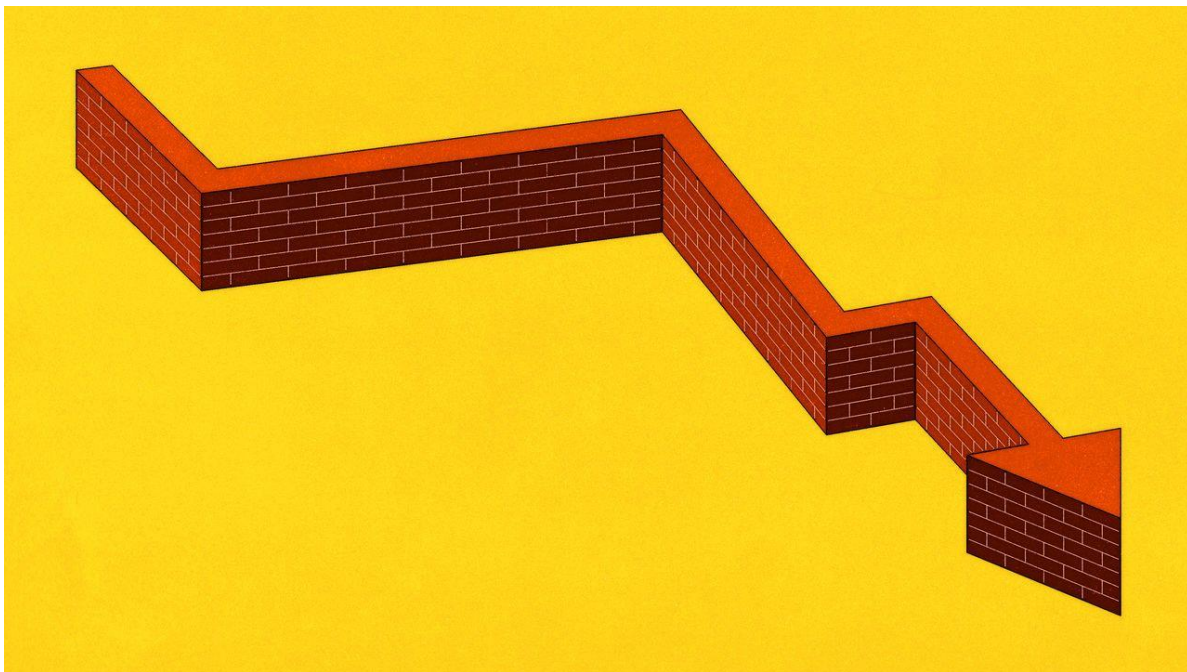


Illustration: Álvaro Bernis

Canada's business press remained sanguine. Belligerent statements by the American president, one Toronto-based newspaper wrote, were mere campaign rhetoric; he would ultimately decide against tariffs that might "arouse resentment in Canada". Such confidence turned out to be gravely misplaced. In 1930 Herbert Hoover signed into law the infamous Smoot-Hawley tariffs, named after their congressional sponsors. The average levy on American imports increased from 40% in 1929 to 60% by 1932, and the global trade system unravelled.

Now the world may be in for a repeat. The Smoot-Hawley tariffs were meant to protect farmers, but grew owing to congressional "logrolling", as representatives sought advantages for their local industries. At the time, few thought the whole package was wise. This newspaper responded to the bill's passage by calling it "tragic-comic". Much the same could be said of today's tariffs. At a minute past midnight on March 4th, Donald Trump imposed 25% levies on Canadian and Mexican imports

(later offering carmakers a reprieve), as well as an extra 10% on Chinese imports, despite the fact there is little appetite among Americans for a trade war with the country's allies, let alone any economic rationale.

What can be learned from the earlier episode? America's Smoot-Hawley tariffs have been blamed for the Depression, but this is inaccurate. Economic historians instead finger unintended monetary tightening as the downturn's cause. The Federal Reserve failed to react to bank collapses, leading money supply to contract. This exacerbated the impact of protectionism: deflation lifted effective tariff rates, which were often levied as cents on the weight of imports, rather than as a percentage of value.

If the direct economic impact of the tariffs has been overstated, their overall impact has not. The worst damage came from the division of democracies into rival trade blocs. During the 1920s the League of Nations, a precursor to the United Nations, managed to negotiate a "tariff truce". The Smoot-Hawley tariffs incensed America's allies, who were infuriated by their economic punishment, but even more so by a sense of betrayal that it had been inflicted by an ally. In 1931 Neville Chamberlain, the British chancellor, set out to institute "imperial preferences", creating a tariff wall around the British Empire. This was brought into reality by the Ottawa Agreements in 1932, signed by Britain, Australia, Canada, India, New Zealand and South Africa. Similar policies in the Dutch and French empires also caused damage. For instance, Japanese exports were shut out of both India and Indonesia, then a Dutch colony, undermining liberals in Tokyo.

This time round, the democracies of the world will hold together: they are exploring how to deepen trade relations. Yet the danger of division is not history's only warning. The Smoot-Hawley tariffs undoubtedly helped one export: anti-Americanism. Cuba, which depended on sugar exports to America, fell into a recession. Its economic collapse led to an anti-American revolution in 1933 and a short-lived government that was overthrown by an American-backed coup. Relations between the two countries have been frosty ever since. Canada's Liberal Party called a snap election after retaliating against America by raising duties on commodities such as eggs and wheat. The even more anti-American and pro-tariff Conservative Party proceeded to win it. Today the Liberals, now seen as more anti-Trump than the Conservatives, are the beneficiaries. They have shot up in the polls ahead of an election that could take place in a matter of weeks.

During the 1930s many countries had treaties with America that prevented them from retaliating with tariffs. Instead, they employed more subtle techniques such as import quotas for cars, then the cutting edge of American manufacturing, as well as bottom-up boycotts. The Italian Royal Automobile Club called for consumers to avoid American cars, saying that it was unpatriotic to be seen driving one. Consider it an interwar equivalent of today's boycotts of Tesla, an electric-car company run by Elon

Musk, who is a close ally of Mr Trump. Kris Mitchener of the Leavey School of Business, Kevin O'Rourke of Sciences Po and Kirsten Wandschneider of the University of Vienna find that, even in countries which did not formally retaliate, imports from America dropped by 15-20% more than economic conditions implied.

Second time also as farce

Tariffs also interacted explosively with monetary policy. The gold standard, an exchange system in which currencies were pegged to the price of gold, was the culprit (as it was for the Fed's mistakes in responding to bank failures). Britain left the gold standard in 1931. Weaker sterling made its exports, and those of its colonies that also used the pound, more competitive, finding extra buyers in foreign markets. This led others to impose higher tariffs on British goods or bring in exchange controls to prevent the outflow of gold from their own treasuries. An inability to secure the currency needed to buy imports did more to stop international trade than tariffs did. At first, America and France defected from the exchange-rate system, hoarding gold, before quitting altogether.

Students of financial crises should worry. Nowadays the dollar, as the global reserve currency, plays a role akin to that of gold in the interwar period. Around half of global trade is invoiced in the currency. Its role is buttressed by America's military might. Indeed, Barry Eichengreen of the University of California, Berkeley, and his colleagues find that countries with American military alliances are more likely to hold dollar reserves, and the Fed is consequently more willing to act as a lender of last resort for the global economy. In 2008 and 2020 swap lines between America and its allies helped prevent a repeat of the Depression. In this new, more transactional world, will such a backstop still be available?

Tecnology

AI models are dreaming up the materials of the future

Better batteries, cleaner bioplastics and more powerful semiconductors await

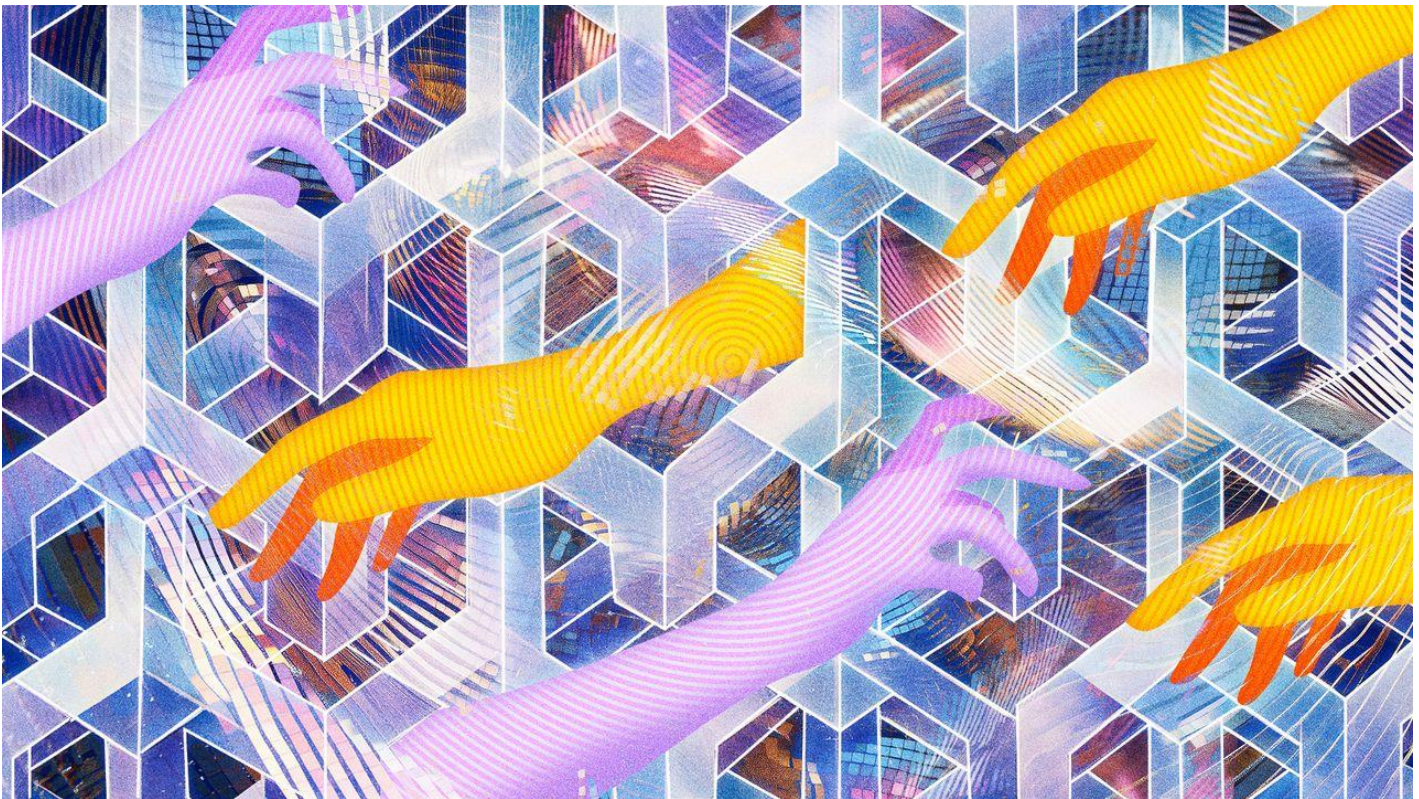


Illustration: Mark Pernice

SCIENTISTS LOOKING to remove carbon dioxide (CO₂) from the air cleanly and cheaply have long been interested in metal-organic frameworks, or MOFs: gigantic, sponge-like molecules that can be precisely engineered to capture the gas and then release it on command.

Made of metal ions held together by compounds containing carbon, MOFs come in a dizzying array of structures, each with its own distinct properties. A MOF capable of absorbing CO₂ at a humid sea-level location, for example, will have a different structure from one that can operate in a dry, high-altitude climate. Sorting through the billions of possibilities to find the right MOF for the job is an

almost impossible task for a human chemist. It is, however, a perfect task for an artificial-intelligence (AI) model.

One startup that is building such a system is CuspAI. It uses a multitude of AI models in concert: some are trained to generate candidate molecules with prescribed properties, which get passed to a specially trained foundation model to assess their properties. CuspAI's goal isn't simply to find a good MOF, but to build a system that can spit out the right one for any environmental conditions—and, from there, to demonstrate that AI can be used to tackle any problem in materials science. Better batteries, cleaner bioplastics, more powerful semiconductors and, potentially, even room-temperature superconductors might soon be up for grabs.

This is no pipe-dream. In a conference paper in November 2024, Aidan Toner-Rodgers, a doctoral student in economics at the Massachusetts Institute of Technology (MIT), analysed the effects of a new AI tool on the productivity of materials researchers at an unnamed American company. Thanks to a staggered launch, with the thousand-odd scientists at the firm getting access to the tool in three distinct groups, Mr Toner-Rodgers was able to treat its introduction like a randomised experiment, and estimate its impact. The results were impressive: a 44% increase in the number of materials discovered, a 17% rise in product prototypes that used those new materials and a 39% increase in the number of patents filed.

Insofar as it can be measured, Mr Toner-Rodgers says, the resulting innovations also seemed to be more genuinely novel. AI-assisted patents were more likely to mention new technical terms, and the materials themselves boasted more unfamiliar physical structures.

But whether you use AI models or not, notes Aaike van Vugt, a Dutch chemical engineer, materials design remains “a pain in the ass”. Some challenges are technical, with the production of new materials often requiring bespoke manufacturing facilities capable of pumping out vast quantities at speed. Others are financial, with companies focusing on early research and development struggling to find a way to turn discoveries into profit.

Other industries have already squared this circle. Stef van Grieken, the co-founder of Cradle, an AI protein lab with offices in Amsterdam and Zurich, describes the pharmaceutical industry as “private equity with laboratories attached”. Clinical trials for new medications may be unforgiving, but they encourage investments that distribute risk and reward throughout the industry, funnelling resources back to the researchers in the trenches. There is no such luxury for materials scientists: those in the business of designing a material must inevitably work out how to test, manufacture and sell it too.

That has not deterred CuspAI. It hopes to build a platform that can design materials to order, leaving it to larger companies with labs and fabrication facilities to do the testing and manufacturing.

MOF to the races

London-based Orbital Materials is also using AI to try to build a MOF. The company has trained its own model from scratch, using supercomputer simulations to generate training data, says Jonathan Godwin, a former researcher at Google DeepMind who co-founded the business. The end result is hundreds of millions of simulated chemical interactions, each made up of just a couple of hundred “tokens”: advanced versions of the terse chemical reactions that fill a high-school textbook. That is orders of magnitude less training data than is required to train a large language model but, Mr Godwin hopes, more than enough to build a small and efficient model that can accurately predict chemical interactions.

But rather than operate as a purely virtual lab like CuspAI, building an AI and selling the discoveries it makes, Orbital is prepared to get its hands dirty. Its foundation model has already spat out a number of candidate MOFs, and Orbital has invested the time and money in in-house labs and chemical engineers to verify that they work and can be manufactured at scale. In December it announced a deal with Amazon Web Services, a hyperscaler, to integrate one discovery into one of the company’s vast data centres, where the waste heat of the air-cooling system will power the chemical reaction that scrubs CO₂ from the air. The goal is to turn the data centre carbon negative, for a cost of 20 cents per hour per chip. If it works, Orbital will have turned an AI-generated invention into a functional product faster than anyone in the pharmaceutical industry.

Other companies are trying to automate away the need for laboratories entirely. Mr Van Vugt, the chemical engineer, is one. His startup, VSParticle, offers what is, in effect, a nanoscale 3D printer: using a technique called spark ablation, it builds up a thin film of novel materials one nanoparticle at a time, following a recipe unique to each material. Such films can be used in batteries or as catalysts. If widely adopted, Mr Van Vugt argues, it could save materials scientists the hard work of figuring out how to physically produce a desired candidate. Instead of worrying about synthesis, they could simply email the recipe to VSParticle’s lab and wait for the end product to be printed in one of the company’s automated fabricators.

Automation has gone further still. In 2023 scientists from MIT showed that an AI-enabled robot could predict, make and analyse almost 300 new chemical dyes, leading to nine engineered to have properties highly desirable in biomedical imaging. In 2024 a group led by researchers at the University of Toronto presented an AI agent that managed (albeit with some help from humans) to create a world-beating gain material—the light-amplifying substance—for a laser.

Using a combination of AI and robotics as a shortcut to synthesising new materials would be huge, says Max Welling, a co-founder of CuspAI. But, he warns, “Recipes are very finicky.” Even minor differences in humidity or air quality can scupper a lab’s chances of making the desired product. That is even truer for labs run by robots, which has led some to question their results. In 2023 researchers at A-Lab, an automated lab at the Lawrence Berkeley National Laboratory, claimed to have made 41 new materials predicted using data from Google DeepMind and the Materials Project, an initiative looking to simulate the properties of all inorganic materials. The announcement was impressive, but questions regarding the model’s analysis have led some chemists to question whether any new materials were actually produced. The A-Lab team stands by their approach.

For now, there is reason for cautious optimism. In November 2024 Meta, a technology giant, announced a partnership with VSParticle and the University of Toronto that has funded the creation, analysis and digitisation of more than 500 experimental electrocatalysts—a category of materials that could be crucial to powering next-generation batteries. The company’s big data centres aren’t always running at maximum capacity, said Larry Zitnick, research director at Meta’s AI division. That left spare computing power which Meta was able to donate to the project to provide the initial simulations for those electrocatalysts.

For Chad Edwards, CuspAI’s other founder, more is at stake than just a new carbon-capture material. If his company’s bet pays off, it would be a chance to show that AI can actually make meaningful contribution to science.

Satellites are polluting the stratosphere

And forthcoming mega-constellations will exacerbate the problem



Photograph: AP

In January more than 100 communications satellites burned up in Earth's atmosphere, vaporising as they crashed towards the planet at about eight kilometres a second. These spectacular exits are intentional, meant to prevent satellites from clogging up orbital real estate or plummeting to the surface in an out-of-control manner. Three years ago the Federal Communications Commission (FCC), an American agency that approves communications-satellite applications, ordered that all such satellites had to fall out of orbit after five years to reduce space debris. Similar regulations apply elsewhere.

Such "designed demise", though well-intentioned, has unintended consequences. When satellites vaporise, they seed the stratosphere (the region of the atmosphere between 10km and 50km above Earth's surface) with particles of constituent metals, including aluminium, copper, lithium and niobium. The quantities were once negligible, but with 11,000 satellites now in orbit—and requests

for another 1m launches lodged with the International Telecommunication Union, an agency at the United Nations—the chemistry of the atmosphere could be about to change on a larger scale. “There’s a lot of concern,” said Daniel Murphy, an atmospheric chemist at America’s National Oceanic and Atmospheric Administration, in November. “We’re putting these materials in, we don’t know what they will do, and they’re going to be going in in ever increasing amounts.”

Earth’s atmosphere has been bombarded by foreign bodies, namely meteoroids and cosmic dust, for billions of years. But this is different. According to a white paper released last year by the European Space Agency, the natural influx of matter into the atmosphere is about 12,400 tonnes a year. In 2019, the most recent year for which data are available, humanity added around 890 tonnes, and that mass is rising.

Moreover, “It’s not just total tonnage; it’s a different set of metals,” says John Plane at the University of Leeds. Space debris injects ten times more lithium into the atmosphere than natural cosmic dust, as well as larger quantities of new exotic metals, he says. In a paper published in 2023, Dr Murphy and his colleagues estimated that one in ten aerosol particles in the stratosphere now contains metals from spacecraft ablation.

How long will these particles linger and what will they do? There are reasons to worry. Particles of aluminium, for example, could combine with oxygen to form molecules of alumina, creating a surface on which other larger chemical reactions can take place. One might liberate chlorine—a known destroyer of the ozone, which keeps Earth safe from ultraviolet radiation—from molecules of hydrogen chloride. Other elements, such as copper, are catalysts, capable of speeding up chemical reactions without being consumed themselves. As the concentration of such catalysts continues to grow, they could carry on accelerating reactions indefinitely.

For now, though, there remain more questions than answers. Researchers around the world are trying to fill the gaps in their knowledge. A lack of monitoring equipment is one challenge. Another is a lack of oversight. Most telecommunications satellites, the most common type of spacecraft, are currently launched by SpaceX in America. The company’s Starlink constellation, which includes almost 7,000 machines, accounts for most of the satellites being sent into space. Although the FCC requires all satellites to undergo an environmental review, those that will be part of mega-constellations, consisting of more than 100 satellites, are exempt. In 2022 the Government Accountability Office, a congressional auditor, recommended that the FCC investigate the environmental impact of larger constellations, but the agency has yet to publish its review into the matter (and did not respond to our requests for comment).

America may not always dominate the atmosphere. China, the European Union and others have plans for satellite mega-constellations of their own. China intends to launch at least three, which are together due to include some 38,000 satellites, and Europe's IRIS constellation will have 290. Rwanda, an unlikely competitor, has filed a request for two constellations with more than 327,000 satellites. The EU and Rwanda are in the process of developing environmental regulations. China's laws do not specify the need for environmental assessment; they do, however, require the space environment to be protected.

There may also be technical solutions. Satellites can be made smaller, even if that is not the current trend. Starlink's spacecraft weigh about 800 kilograms at launch, and Elon Musk, SpaceX's boss, predicts future generations will be even heavier. Some scientists have suggested alternative construction materials, such as carbon fibres or wood, which could reduce the need for exotic substances. Yet these may have negative consequences of their own. Wood, for instance, could incinerate upon being decommissioned, releasing lots of black soot into the atmosphere, which would trap heat and possibly darken the sky.

Another focus is a satellite's final moments. "The dominant thinking about re-entry was that all of the material would stay in pieces large enough to just fall out of the atmosphere and not accumulate in the stratosphere," says Martin Ross, of the Aerospace Corporation, an American firm. This has turned out to be wrong. Some researchers argue that the FCC needs to rethink its five-year rule and extend the lifetime of commercial satellites, in order to avoid the need for so many future launches. Others suggest mega-constellations could be shared between countries. As international tensions rise, however, that idea may turn out to be pie in the sky.